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OVERVIEW OF CONTROLS FOR CHLOROFLUOROCARBONS

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16. ABSTRACT The paper gives an overview of controls for chlorofluorocarbons (CFCs). Responding to concerns regarding the potential for stratospheric ozone depletion, the U.S. has joined other nations in pursuing an international agreement to limit the emissions of fully halogenated CFCs and certain halons. To implement the Montreal Protocol in the U.S., the EPA has proposed a national regulation to limit the production of these substances by the allocation of production quotas to firms engaged in this activity in 1986. Many ways exist to achieve the needed reductions. This paper discusses the various control options with some advantages and disadvantages, for the major industries that use CFCs and halons.

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Pollution	Pollution Control	13B
Fluorohydrocarbons	Stationary Sources	07C
Ozone	Chlorofluorocarbons	07B
Stratosphere	Stratospheric Ozone	04A
Halogenation	Halons	
Bromohydrocarbons		

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ABSTRACT

In response to concerns regarding the potential for stratospheric ozone depletion, the U. S. has joined other nations in pursuing an international agreement to limit the emissions of fully halogenated chlorofluorocarbons (CFCs) and certain halons. In order to implement the Montreal Protocol in the U. S., the Environmental Protection Agency (EPA) has proposed a national regulation to limit the production of these substances by the allocation of production quotas to the firms engaged in this activity in 1986. Many ways exist to achieve the needed reductions. In this paper the various control options with some advantages and disadvantages are discussed for the major industries that use CFCs and halons.

INTRODUCTION

On December 1, 1987, new domestic regulations restricting production and consumption of ozone-depleting CFCs were proposed by the EPA Administrator. (Ref. 1) The proposed rules would fully implement the Montreal Protocol, (Ref. 2) if it enters into force. EPA's assessment of the risks of ozone depletion indicates that the Protocol's control requirements are an appropriate response.

The Protocol leaves it up to each party how to achieve the required reductions in production and consumption. EPA's goal in implementing the Protocol is to provide the marketplace with flexibility to achieve the required reductions in the most economically efficient manner possible. Two general approaches for achieving the Protocol's required reductions of controlled substances were evaluated. One approach relies on market incentives to achieve low cost reductions in the use of CFCs and halons. Under this approach EPA could either directly restrict the supply of CFCs and halons or assess a regulatory fee on their use. Either would increase the cost of using CFCs which would give those firms with relatively low-cost reduction options an economic incentive to reduce their use of these chemicals. Those firms where no such reduction opportunities exist would continue to use CFCs, although they would have to pay a higher price. Three alternative economic incentive approaches were evaluated: marketable rights based on auctions, marketable rights allocated by quota to past producers and importers, and regulatory fees.

The second general approach is to use the traditional engineering controls and product or chemical bans. It involves EPA's deciding which specific industries or uses of CFCs and halons should be regulated. This approach is the usual way EPA regulates pollution. It was considered alone, and as a supplement to allocated quotas based on the extent to which CFC users may be postponing the adoption of low cost or easy to implement reductions.

EPA evaluated each of these options in light of the following criteria: certainty of achieving the desired environmental goal, economic costs and efficiency in meeting that goal, administrative costs and enforceability, legal certainty, and impacts on small business. EPA decided to implement the Montreal Protocol using a system of allocated quotas. Quotas reflecting the allowable level of production and consumption will be allocated to each of the firms who engaged in these activities in 1986. Trading of allocated quotas will be permitted. Exports and imports of the restricted chemicals will be allowed consistent with restrictions contained in the Montreal Protocol. EPA believes that this approach will provide a low-cost means of achieving its regulatory goal, spur technological innovation, minimize administrative requirements, and facilitate enforcement. EPA is also considering the development of specific regulations limiting CFC and halon use for particular industries to supplement allocated quotas.

A Regulatory Impact Analysis (RIA) to evaluate the costs and benefits of "major rules" is required by Executive Order. The RIA for Protection of Stratospheric Ozone which was completed in December 1987 (Ref. 3) evaluates various control options for CFCs. The control options evaluated in the RIA were divided into chemical substitutes, product substitutes, and add-on engineering controls/process substitutions. Several factors were considered in assessing the potential emission reduction, capital expenditure, and operating costs for each control. Factors considered with respect to technical feasibility included compatibility with existing equipment, the ability to maintain system efficiency and reliability, and availability of sufficient experience for commercial application. Economic factors of interest included direct capital and operating costs, outlays for system application testing, plant retooling, and secondary costs such as disposal of waste product and increased warranty claims. In addition, social factors such as safety, worker health, and retraining of service personnel were considered although many of these areas are difficult to quantify.

CONTROL OPTIONS

Industry will use a combination of control options in meeting potential CFC regulations. In the RIA, these controls were evaluated and the more favor-

able options identified. (Ref. 4) The controls that appear most likely to be adopted by each application area were identified in the RIA and are listed in Table I. These control options are described briefly in the following sections.

Chemical Substitutes

New Chemical Substitutes. HFC-134a appears to be the most promising substitute for CFC-12. Since the physical properties are very similar to CFC-12, a major equipment change for refrigeration and air conditioning applications may not be required. It is close to CFC-12 in operating efficiency. Some drawbacks include a lack of a compatible lubricating oil and higher cost. Toxicity tests to date have shown low toxicity, but final toxicity test results will not be available for about 5 years.

HCFC-123 appears to be the most promising substitute for CFC-11. Limited testing as a blowing agent for rigid polyurethane foam has revealed both positive and negative results. It has performed well in some formulations and has a slow diffusion rate through the polymer material. Drawbacks include slighty higher solvent action, higher thermal conductivity, and higher cost. HCFC-123 is also a potential substitute for CFC-113 in solvent metal and electronic cleaning. HCFC-123 is a very agressive solvent and has a much lower boiling point than CFC-113 which may limit its use. HCFC-123 is also a potential substitute for CFC-11 used as a refrigerant in centrifugal chillers.

HCFC-124 may be a suitable substitute for CFC-12 as a blowing agent in rigid extruded polystyrene foam sheet, extruded low density polyethylene foam, low density polypropylene foam, and polyvinyl chloride foam. Since its diffusivity through the foam is high, it could cause foam collapse.

Currently Available CFCs and CFC Blends. One control option to reduce the use of CFC-11 blowing agent in rigid polyurethane pour-in-place foam is to use more water in the formulation. It may be possible to achieve 100 percent replacement of CFC-11 with water in rigid polyurethane packaging.

HCFC-22 is used as a refrigerant in retail food refrigeration and in commercial air conditioning. It has an ozone depleting factor only 5 percent that of CFC-12. Substitution for CFC-12 will require significant design changes because it: requires a 50 percent higher operating pressure, has reduced oil solubility which affects compressor lubrication, and has a high permeation rate through elastomer hoses.

Several blends containing HCFC-22 hold promise for use as substitutes including:

CFC-502, an azeotropic mixture of 48.8 percent HCFC-22 and 51.2 percent CFC-115, is used in all of the low-temperature and 40 percent of the medium-temperature refrigeration systems in retail food stores. CFC-502 is a

potential substitute for CFC-12 systems even though one of its components is controlled under the Protocol. Overall, CFC-502 has a lower ozone depletion potential than CFC-115 alone or CFC-12 alone. The Protocol requires only a reduction in total weighted production/consumption, not in each controlled substance individually.

A HCFC-22/-142b non-azeotropic mixture of 40 percent HCFC-22 and 60 percent HCFC-142b is tailored to closely match CFC-12. This mixture has a good potential for use in small hermetically sealed units such as home refrigerators and as an aerosol propellant.

A CFC-11/HCFC-22 mixture can be used in place of CFC-12 in polyurethane poured and sprayed foam. However, the substitution would result in only a minor reduction in ozone depletion potential. This and other drawbacks (e.g., poor HCFC-22 solvency and potentially higher diffusion rate) will limit the use of this substitute.

A HCFC-22/hydrocarbon mixture has been found to be an acceptable substitute for CFC-12 as a blowing agent for extruded polystyrene sheet.

Dimethyl ether/HCFC-22 mixtures have been used to replace CFC-11 and -12 in some essential aerosol applications.

Solvent Substitutes. A wide variety of organic solvents are used in electronic and metal cleaning including petroleum solvents, chlorinated hydrocarbons, and CFCs. It is postulated that petroleum solvents or methyl chloroform will be selected where possible as the short term replacement for CFC-113 in solvent cold-cleaning applications. Methyl chloroform and methylene chloride are expected to be the solvent replacements of choice for vapor degreasing. Dry cleaning applications are expected to switch to perchloroethylene or methyl chloroform. A new product which contains a terpene hydrocarbon-based cleaner has recently been announced which can be used to replace CFC-113 for some solvent cleaning and degreasing.

Methylene chloride also competes with CFC-11 as a blowing agent for flexible polyurethane foam. Wider use of methylene chloride is expected for this application.

A major barrier to expanded use of methylene chloride as a blowing agent or solvent replacement is the potential for future regulation of in-plant exposure and stack emissions.

Sterilant Substitutes. Control option "10/90 (EO/CO_2)" refers to replacing 12/88 (a 12 percent ethylene oxide and 88 percent CFC-12 mixture) with a 10 percent ethylene oxide and 90 percent CO_2 mixture. Control option "N_2 purge, then pure EO" refers to a process where the sterilization chamber is purged with nitrogen before sterilizing with pure ethylene oxide. Control option "HFC-134a/EO mixture" refers to the replacement of CFC-12 in the 12/88

mixture with HFC-134a. All three of these options are expected to be used to replace the 12/88 sterilant. The 10/90 (EO/CO_2) has a disadvantage of requiring a much higher operating pressure than 12/88. The N_2 purge, then pure EO option requires the use of pure ethylene oxide which is explosive; therefore, equipment changes are needed to handle the explosive gas. The HFC-134a/EO mixture is still in the development stage and may not be available for 5 to 7 years.

Currently or Previously Used Substitutes. When polystyrene foams were first introduced in the mid-1960s, they were blown almost exclusively with pentane. Industry has shifted away from pentane because of the fire hazards. It is possible to make virtually all thermoformable polystyrene foam sheet using hydrocarbons such as pentane for the blowing agent. Hydrocarbons such as ethylene, ethane, propane, propylene, and methane are used as refrigerants in large industrial refrigeration systems in petrochemical plants. The use of hydrocarbons is restricted by codes and regulations since they are highly flammable.

Ammonia is currently used as a refrigerant in most food processing plants, cold storage warehouses, ice houses, skating rinks, and a percentage of the chemical/petrochemical plants. The use of ammonia is restricted since it is both toxic and flammable.

CO_2 has been used as an aerosol propellant but suffers from poor atomization, varying pressure over the life of the can, and occasional inability to expel the entire contents of the can. Some improvements in technology have reduced problems with CO_2, but they have not been completely eliminated.

Product Substitutes

Alternate Insulating Materials. Rigid foam laminated boardstock is used routinely in the construction of a variety of new buildings and as retrofits in existing buildings. The most likely short-term candidate control option for reducing use of CFCs in these applications is to simply use other insulation materials coupled with modified construction design and/or thicker materials to achieve equivalent energy efficiency (e.g., thick fibrous glass batts with thick walls and wide stud spacing).

Substitute Food Containers. Since the 1960s, polystyrene foam products have gradually replaced competing products fabricated from traditional materials. The benefits of polystyrene foams (e.g., light weight, strength, ease of forming, moisture resistance, low cost, and thermal insulation properties) have spurred this growth. With few exceptions, the polystyrene foam serves essentially the same purpose as the material it has replaced. Materials that can be used in place of the CFC blown polystyrene foam sheet for food packaging include hydrocarbon blown polystyrene, solid plastic, plastic film wrap and bags, and paper and foil wraps.

Alternate Packaging Materials. Low density polyethylene and polypropylene are used in a wide variety of applications, from packaging material to athletic equipment. They have unique properties including: cushion effectiveness at a given thickness, unique vibration dampening response, multiple drop protection, strength, creep resistance, minimum package weight and size, low shipping cost, and static discharge protection. Because of these properties, these foams are often used in specially designed package systems such as for a delicate computer product or military weapon. In these applications, replacements may not be readily available. For other applications, alternative products such as expanded polystyrene (EPS) bead, water-blown polyurethane foam, plastic film bubble wrap, and other paper and plastic packaging products can be used.

Alternate Gasket/Flotation Device Materials. Low density polyethylene and polyvinyl chloride foam are used in gasket and sealing materials and in flotation devices. Gaskets can be made from rubber, plastic, or paper products. Flotation devices are still made from air-filled plastic or sealed fabric. EPS bead is also used for flotation.

Alternate Cushioning Materials. Flexible polyurethane foam is the predominant cushioning material, due to its combined advantages of low price, durability, and versatile physical properties. A degree of conversion to technologies that were replaced by flexible polyurethane (e.g., latex foam, built-up cushioning, and natural and synthetic fiberfill) are technically feasible.

Switch to Disposables. To eliminate the need for hospitals to sterilize on site with the sterilant gas mixture 12/88, one control option is to switch to disposables. All items needed for a single surgical procedure would be packaged and sterilized by the manufacturer of the disposable products.

Modified Stirling Cycle. Modified Stirling cycle refrigerators have been used historically for exotic applications such as aerospace and cryogenic cooling. One company is marketing a refrigerated truck trailer using a modified Stirling cycle.

Add-On Engineering Controls/Process Substitution

Recovery/Recycle. The refrigerants from refrigeration and mobile air conditioning equipment can be recovered and recycled at rework, service, and disposal with the use of portable devices which capture the refrigerant from a system rather than vent it to the atmosphere. More seriously contaminated refrigerants can be collected and then cleaned in a central facility, remanufactured, or destroyed. Much of the waste solvent from solvent cleaning operations can be reclaimed by the use of on- or off-site distillation.

Alternate Leak Test Gas. Mobile air conditioning and refrigeration equipment must be leak tested at manufacture, installation, and service. The high ozone depleting CFC-11 and -12 refrigerants which are used to charge the systems are usually selected for leak testing to reduce chances of the refrigerants' being mixed. CFC emissions can be reduced by switching to a less ozone depleting CFC such as HCFC-22 or to a different gas such as helium.

Market Mix. This concept addresses demand for new centrifugal chillers. It is suspected that a portion of future demand for chillers which use high ozone depletion refrigerants can be shifted to units using a lower ozone depleting refrigerant such as HCFC-22. For example, CFC-11 centrifugal chillers are known to be widely used in the range of 300 to 1000 tons (270 to 900 metric tons) of capacity. The market mix option assumes that a fraction of future installations which would use CFC-11 centrifugal chillers could instead use HCFC-22 helical screw chillers (either singly or as multiple part-capacity units).

Quality Engineering. Leaks from mobile air conditioners can be reduced by improvements in design of system components such as the use of shorter and less permeable hoses or the addition of features such as a refrigerant level sensor to shut off the system and alert the driver that the charge has dropped below a certain level. These "quality engineering" improvements could be installed at the factory as original equipment or used as replacement parts on mobile air conditioners after manufacture.

Water Blown HR Systems. Additional use of water-blown high-resiliance (HR) chemical systems for molded flexible foams is a realistic possibility for substantial emission reduction. There may be a penalty in foam versatility, cushioning properties, and part reject rates.

Minimum Foam Density. Most of the auxiliary blowing agent, CFC-11, used in flexible polyurethane foam is used for low density foam. CFC-11 emissions can be reduced by establishing a minimum foam density specification.

Add-on Controls. Add-on engineering controls can be used to reduce CFC-113 emissions from solvent cleaning operations. These controls include covers, optimum freeboard height, and adequate drainage of parts being cleaned via drainage racks, hooks, automatic hoists, or equivalent techniques.

Carbon Adsorption. Carbon adsorption is currently used to collect CFCs from a variety of applications for recovery or disposal. A broader use of this technology is technically feasible.

Food Freezing Alternatives. Liquid food freezing uses liquid CFC-12 to quick-freeze foods. Air blast freezing and cryogenic freezing can replace liquid food freezing. Air blast freezing blows cold air upward through mesh

belts carrying the food product. Cryogenic freezing uses liquid nitrogen or liquid carbon dioxide sprayed onto the food.

Aqueous Cleaning. Aqueous cleaning is an alternative to metal and electronics cleaning with CFCs. No solvent emissions occur from this type of cleaning because the cleaning fluid is water-based.

No Clean Option. A long term option for cleaning of electronic circuit boards is the "no clean approach." This approach would use different fluxes which would not need to be removed from the circuit board.

Hot Vapor Recycle. This is a technique for the control of carry-out solvent loss from conveyorized solvent vapor degreasers. Hot superheated vapor, supplied to a dryer in the degreaser, heats the part being cleaned above the solvent vapor pressure. This method can remove trapped solvent in spaces as small as 0.05 to 0.08 mm.

Improve Controls/Training. The most direct way to reduce unwanted discharges from halon total-flooded fire protection systems which release the entire quantity of halons into an enclosed space is to use improved detection and control equipment. Increasing training of personnel working in halon system protected areas can also significantly reduce releases due to unwanted discharges and fire emissions. Using halon-121 (HCFC-22) as a substitute gas for testing total-flooded fire protection systems can reduce emissions of the high ozone depleting halons.

SUMMARY

On December 1, 1987, EPA proposed domestic regulations that will fully implement the Montreal Protocol to protect the stratospheric ozone layer. It was decided that allocated quotas offer the most attractive approach to limiting the use of CFCs and halons. This approach should provide for economically efficient reductions. It involves a minimum of administrative costs, is the most easily enforced option, and does not raise any potential legal issues that might result from other options.

Control options that might be used by industry to achieve the necessary CFC reductions are evaluated in the RIA. The most likely long-term control option which may be adopted by most application areas is a chemical substitute. With this option, it may be possible to eliminate 90 percent or more of the ozone-depleting CFC emissions. A variety of control options hold promise for short-term applicability. Some of the engineering controls may still be applied even after new chemical substitutes (e.g., HFC-134a and HCFC-123) are in use, since the higher cost of these substitutes may justify recovery. EPA is also considering the development of specific regulations limiting CFC and halon use for particular industries to supplement allocated quotas.

REFERENCES

1 Federal Register, pp. 57,489 - 57,523, Vol. 52, No. 239, December 14, 1987.

2 Montreal Protocol on Substances that Deplete the Ozone Layer, Final Act, United Nations Environment Programme, September 1987.

3 Regulatory Impact Analysis: Protection of Stratospheric Ozone, Volume I: Regulatory Impact Analysis Document, Prepared by Office of Air and Radiation, U. S. Environmental Protection Agency, Washington, DC, December 1987.

4 Regulatory Impact Analysis: Protection of Stratospheric Ozone, Volume III: Addenda to the Regulatory Impact Analysis Document, Prepared by Office of Air and Radiation, U. S. Environmental Protection Agency, Washington, DC, December 1987.

Table I. Control options considered most likely to be adopted

Option	Application[a]						
	1	2	3	4	5	6	7
CHEMICAL SUBSTITUTES							
HFC-134a	LT[b]	LT	LT				
HCFC-123	LT	LT	LT			LT	
HCFC-124	LT						
CFC-11/Water	ST						
HCFC-22			ST				
CFC-502			ST				
HCFC-22/HCFC-142b			MT	ST			
CFC-11/HCFC-22	ST						
HCFC-22/Hydrocarbons	ST						
DME/HCFC-22						ST	
Petroleum Solvents						ST	
Methyl Chloroform						ST	
Methylene Chloride						ST	
Perchloroethylene						MT	
10/90 EO/CO_2					ST		
N_2 Purge/Pure EO					ST		
HFC-134a/EO					LT		
Hydrocarbons	ST		ST				
Ammonia			ST				
CO_2				ST			
PRODUCT SUBSTITUTES							
Alternate Insulating Materials	ST						
Substitute Food Containers	ST						
Alternate Packaging Materials	ST						
Gasket/Flotation Alternatives	ST						
Alternate Cushioning Materials		ST					
Switch to Disposables						ST	
Modified Stirling Cycle			ST				
ADD-ON CONTROLS/PROCESS MODIFICATION							
Recovery/Recycle			ST			ST	ST
Alternate Leak Test Gas			ST				ST
Market Mix			ST				
Quality Engineering			MT				
Water Blown HR Systems		ST					
Minimum Foam Density		ST					
Add-On Controls						ST	
Carbon Adsorption	ST						
Food Freezing Alternatives				ST			
Aqueous Cleaning						ST	
No-Clean Option						LT	
Hot Vapor Recycle						LT	
Improve Controls/Training							ST

[a] Application: 1 - Rigid Foam, 2 - Flexible Foam, 3 - Refrigeration, 4 - Miscellaneous, 5 - Sterilants, 6 - Solvents, 7 - Halons

[b] Availability: ST - Short Term, MT - Medium Term, LT - Long Term